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The Planning and Fitting up of School Laboratories

BY

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(*Indian Educational Service*)

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LIST OF PLATES.

LIST OF ABBREVIATIONS USED IN PLATES.

A. Tall almirahs for apparatus.
B. Wall bracket.
D. B. Blackboard.
B. S. Bracket shelf.
C. Wall cupboard with table top.
C. D. Do. with balances above them.
D. T. Demonstration table.
D. P. Sloping drain pipe.
D. F. Diagram frame.
G. Gallery.
G. F. Glazed frame.
G. D. Guides for drawers.
G. P. Gas pipes.
G. T. Gas taps.
H. Hooks.
L. Optical lantern.
L. S. Lantern screen.
L. T. Lecture table.
N. S. Shelf for note-books.
O. S. Sinks with syphon outlets.
P. Platform.
P. P. Partition plank in cupboard.
R. Recess for long tubes, etc.
R. P. Reeper partition.
S. Sink.
S. B. B. Squared blackboard.
S C. Spring catches.
S. P. Shelf plank.
S. T. Stops for drawers.
W. Gangway.
W. B. Working bench.
W. P. Water pipe.
W. S. Wooden stop with screw adjustment.
W. T. Water tap.
W. V. Instantaneous grip vice for wood

PREFACE.

SCIENCE teaching on up-to-date lines is engaging at present the attention of the Department of Education and consequently laboratories on model lines will have to be fitted up ere long in each institution. The following pages have been written in the belief that they will be of some use to those who are engaged in the planning and fitting up of laboratories.

When the additions to the Physics laboratories of the Presidency College were in progress, under the guidance of Mr. R. Ll. Jones, I learnt the technique of the subject. Subsequently the responsible task of fitting up the science laboratories at the Teachers' College, Saidapet, and the Ceded Districts College at Anantapur was entrusted to me by the Director of Public Instruction. The experience thus gained, the frequent references made to me on the subject both by my past students who are science teachers in schools and by the Educational Department, and the observations made during the visits paid by me to laboratories in various high schools and colleges were recorded from time to time. I have attempted to present them here in a readable form. Not the least amongst the factors that led to the bringing out of this publication is the encouragement I received from the Hon'ble Mr. R. Littlehailes, Director of Public Instruction.

It is difficult to give any information of practical value applicable under all conditions; but those who are entrusted with the work of laboratory construction will, I trust, find useful hints in these pages, that may be adapted to suit their local conditions. The fittings, etc., of advanced laboratories, each of which has to be planned and fitted up to meet its special requirements, have not been included in the scope of this pamphlet.

This is not perhaps the proper place to acknowledge my indebtedness to Mr. R. Ll. Jones, the late Professor of Physics, Presidency College, Madras, under whom I had the unique privilege of having studied and served for nearly ten years, for all that I have learnt under him, but most of the suggestions

that have been made are mainly the outcome of the advice and instruction I received at his hands from time to time, on the subject.

A pamphlet of this nature would be of little use without the addition of numerous diagrams illustrative of the descriptions contained, and I wish therefore to acknowledge the valuable services rendered in this behalf by my brother, Mr. M. S. Srinivasa Rao of the Public Works Department, who, at considerable personal inconvenience, undertook this labour.

M. C. S. A.

MADRAS.
7th July, 1921.

THE PLANNING AND FITTING UP OF SCHOOL LABORATORIES.

Introduction.

Practical instruction in Chemistry and Physics is now acknowledged to be a necessary accompaniment to all theoretical or class instruction in these subjects. This practical work requires suitable rooms and fittings.

Although the value of the work carried on in school laboratories depends mainly on the enthusiasm and ideals of teachers and the apparatus at their command, the influence of surroundings cannot be over-estimated. Well planned, well lighted, well ventilated and neatly maintained laboratories encourage pupils both morally and physically to do good work.

The planning and furnishing of laboratories often engage the attention of science teachers, the Department of Education and engineers, each of whom has to share the responsibility in adapting the design and arrangement of laboratories to the numerous and varied local conditions.

Owing to the increase in the strength of schools and the importance attached to laboratory training in the modern system of education, many schools find their present accommodation inadequate and unsuitable, and the question of the provision of laboratory accommodation and equipment on a more satisfactory basis will ere long have to be tackled. When an attempt is made to convert into a laboratory an existing building or a set of rooms not specially designed for the purpose, much inconvenience and unsightliness are often caused, and hence it is necessary that the arrangement of all the proposed fittings should have been previously thought out and decided upon by the educational officers concerned, before entrusting the execution to the engineer.

Some type designs of laboratory rooms, of working tables, etc., have been given, and the general principles involved in their making have been discussed.

Laboratory planning and equipment from the teacher's rather than from the architect's point of view is the theme of the following pages.

Diverse as may be the opinion of teachers as to the position of benches and the choice of fittings, all will probably agree that no effort should be spared to attain the following five objects:—

1. The laboratory should be capable of expansion and modification to meet the growing needs of the school and be compact in arrangement.

2. Fittings and furniture should be so planned as to have all their parts easily accessible and be convenient for use and economical in the long run.

3. Fittings should be so disposed around the room as to minimise the unavoidable movement of pupils.

4. The arrangement of benches should ensure ease of supervision on the part of the teachers.

5. The storage accommodation should be ample, and wall space should be left for additional fixtures.

Individual attention to pupils will have to be bestowed in practical classes and a teacher should not be in charge of more than 20 pupils. When the strength increases, a demonstrator should help in conducting the practical classes

No quantitative experiment can ordinarily be carried out by beginners in less than an hour and hence consecutive periods should be set apart for such lessons. They should preferably be the last two periods of a school day, as extra time will be needed by pupils who are a little slow.

The subject "care of fittings and apparatus" is not properly speaking, germane to the topics dealt with here; but as the upkeep of a laboratory in an efficient condition involves special attention to these, some hints and suggestions have been appended.

2.—*Accommodation for general science.*

Owing to the importance that is now attached to the training of the eye and hand simultaneously with the mind, practical

work in science is recommended to be commenced early in the school course. Such work consists chiefly of a few lessons on elementary principles of chemistry and physics, and in practical mathematics, with simple experiments on familiar substances and some physical measurements. Pupils in middle schools (*i.e.*, those of ages below 11 or 12) are not sufficiently trained in observation and manipulation to benefit by a systematic course in experimental science. Nature study, *i e.*, the observation of natural phenomena and familiar things, and the making of simple records of their observations is a part of their training and with simple appliances such as a knife, a pocket lens, and scalpels, simple examination of objects can be made in the garden and in the school room on specimens collected for the purpose. Practical work in physics and chemistry is usually commenced in Form IV.*

Animal and plant life, which provides the main topics for the elementary science course in lower secondary forms, needs only a garden and a class room. Natural phenomena (meteorological, geographical, astronomical and industrial) which are observed as they occur in nature during excursions, need no special laboratory. In lower secondary or middle schools, a small room with an almirah, cupboards and a table will be sufficient to stock all the apparatus, chemicals and materials required for teaching elementary science, and the apparatus needed for any lesson may be easily conveyed in suitable trays to the class room. A small glazed notice board 3 ft. by 3ft. and 3 in. deep, where the local meteorological records, the Presidency weather charts, etc , are posted, may be fixed up in some prominent place easily accessible to all pupils.

The experimental science work which is begun in Form IV[1] requires a special laboratory room, with simple fittings for pupils' work and stores. Here the pupils are introduced to the elementary principles of science which are required for the study of the more advanced sciences like physiology, hygiene, physical geography, etc. These principles can only be learnt through experiments. Plate 1 indicates a suggested arrangement of the fittings in a room where the teaching is of this elementary

* Form IV is, in Madras the lowest class of the upper secondary department

[1] " Experimental lesson " means a lesson in which experiments are performed before a class by the teacher to illustrate laws or to generalise from their results.

nature. The teaching and the practical work[1] where the strength permits, may be done in the same room.

It will be observed from the plate that the working benches[2] are arranged parallel to the demonstration table[3]. The pupils, who usually work in pairs, all face the teacher. They are provided with stools to sit on, and the benches are so arranged as to allow the teacher easy access to every pupil. There should be a minimum distance of 2 ft. 9 in. between two benches. The length of bench space allotted to each pair of pupils should be about 3 ft. 6 in. to 4 ft. The benches should be about 1 ft. 6 in. wide and 2 ft. 8 in. high, with a vertical board 6 in. high fixed to the end of the bench opposite the pupils to prevent the apparatus placed on the table from falling off. Teakwood tops for the tables with French polish will generally meet the requirements. The tables provided should in every case be simple, strong and steady.

A drawer 6 in. deep below the bench top, should be provided for each seat to enable pupils to place their books and keep the table free for apparatus and notebooks.

Bottles, test-tubes, etc., needed for experiments, may be kept in shelves arranged at the ends of the benches or on the adjoining walls so that they may be easily put on the working benches.

A generous supply of cupboards will be required for storing apparatus. They may be placed along the wall. If the cupboards are about the same height as the working benches, their tops can be used as tables.

A shelf for pupils' record books should be fixed to the wall, preferably near the entrance into the class room, as disturbance to the class at work when the books are placed on or removed from the shelf by other pupils is thus obviated.

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[1] "Practical lesson" is one in which pupils handle apparatus themselves and do some experiments under the teacher's guidance.

[2] A "working bench" means the table used by pupils for accommodating the apparatus handled by them during their practical work

[3] "Demonstration table" means the table used by the teacher whereon he handles apparatus needed for his teaching. The demonstration table is placed on a low platform from which the teacher may have a view of all the pupils while they are at work.

The demonstration table need not be more than 2 ft. wide and 6 ft. to 8 ft. long. There should be a black board of ample dimensions on the wall behind the table and teacher.

When water is supplied to working benches, separate sinks to each seat are unnecessary. A few sinks may be fixed to the wall in convenient places, or may be placed at the ends of one or two benches. In chemistry work pupils should be provided with small waste basins for collecting the waste liquids while they are at work. The basins may be emptied and cleaned at the end of the lesson.

The same benches may be used both for chemistry and physics. Separate lecture rooms and separate practical class rooms are not required for these elementary classes, as the lessons are mainly practical, and teaching and demonstration occupy but a small part of the lesson. The teaching sometimes comes at the beginning and at other times at the end of a lesson.

3. *Elementary Laboratories.*

The general science course is the compulsory science part of a scheme of secondary education prescribed for all the forms, and the accommodation needed for such work has been described in the previous section. There are more detailed and advanced courses in physics and chemistry which are selected by pupils as optional subjects during the last two years of the secondary course. For these courses better equipment and accommodation are required, as the pupils work individually and not in pairs. Quantitative experiments, which are often attempted in this course require more apparatus, involve varied manipulation and need more space.

One of the following arrangements is suggested, the choice depending upon the number of teachers employed, number of divisions in each form and strength of each division :—

1. A combined chemical and physical laboratory.
2. A combined lecture and practical class room for each subject.
3. Separate laboratories and a common lecture room.
4. Separate laboratories and separate class rooms.

I. Combined Chemical and Physical Laboratory.

Where the strength of the science section is limited and a single teacher is in charge of all the science work, such an arrangement may be permitted, and a single room can serve both as a chemical and physical laboratory. There are many disadvantages, however, in such an arrangement. Delicate physical instruments and apparatus may be spoiled by the fumes and moisture that are inseparable from chemical work. The reagent shelves that have to be placed on the tables and the sinks which are needed at each seat for chemistry work militate against the free use of physical apparatus, and a class in chemistry cannot be immediately followed by one in physics as the removal of the apparatus used in the previous lesson and the arranging of that required for the new lesson will cause delay in class work. As plenty of wall space and of cupboard space below working benches is required for the storing of common apparatus and reagents and of the 'individual' apparatus needed for chemical work, the physical apparatus will necessarily have to be stored at some distance, and thus inconvenience will be felt in putting them on the work tables, and breakages will not be uncommon. Again, working benches have to be made so as to suit both kinds of work. An ordinary chemical working bench with its sinks will have to be provided with flush covers and portable reagent shelves to make it serviceable for physical work.

II. A combined Lecture and Practical class room for each subject.

Where the class is not large (not exceeding 20) a single room for each subject can be fitted up both for teaching and practical work. This is an economical arrangement. The single working benches [1] round a demonstration table will be sufficient to accommodate the pupils when attending the theoretical classes, and the double benches [2] beyond will accommodate them for practical work. (See plate 3.) The side tables along

[1] A 'single' working bench is a narrow table which allows pupils to work at one side only.

[2]. A 'double' working bench is broader and allows two sets of pupils to work at it, the sets facing each other.

the walls will also provide extra space which may be required for certain experiments in the practical classes when the aature of the experimeuts will nat admit of pupils working close to each other. The plan elevation and sections af a demonstration table with single working benches arranged round it are given in plate 2.

A demonstration tablo raised an a low platform is useful for purposes of supervision besides serving as a lectare table. The beight of the platform may be from 6 in. to 12 ia. and the height should be regulated by the distance of the farthest bench. The platform should extend to at least 3 ft. 6 in. behind the table to allow for the free movement of the teacher, and a black-baard should be provided on the wall behiad the platform. The demoastration table aeed aot be more than 2 ft. broad aad 10 ft. long.

Balances can he kept in cases in the samo room if fume cupboards are provided in the adjoiniag veraadahs aad stroag acids are aot permitted ta be boiled ia large quantities ia the laboratory itself.

Plate 3 gives (1) a plan of the arrangemeut of beaches and tables in a combined class aad practical work room iatended to accommodate 20 pupils, aad (2) a longitudinal section of the room showiag the relative heights aad positioas of wiadows.

The fittings given in the plate are intended for physics work; slight modifications will be required for chemistry work.

The double working benches should give each pupil a space of at least 3 ft. in length and 2 ft. in breadth, and pupils may work facing each other. Cupboards should he provided below the tables. In the physical laboratory, two sinks, one near the teacher and the other at a central place on the wall, will quite suffice. The apparatus needed for demonstration and practical work should he neatly arranged on the tables placed along the walls and in the cupboards under the working benches. Balances may be placed on shelves fixed to brackets attached to walls and above the wall cupboards. (See fig. 1.)

The following modificatians will have to be made to adapt the working benches, etc., noted in plate 3 to chemistry work. A large sink with bigh taps shanld be fixed in one of the corners

for cleaning large jars, bottles, burettes, etc.; (see fig. 2). Water may be laid on to each seat, and small sinks with suitable drain pipes should be fitted up. There must be a small room adjoining the laboratory where glassware and chemicals may be stored, and where arrangements for experiments may also be made by the teacher in advance of a lesson. The space below the benches will have to be partitioned so as to accommodate the apparatus entrusted to individual pupils. The general apparatus and chemicals will have to be stored in wall cupboards and in bottle shelves. (Details of chemical working *benches, wall cupboards and bottle shelves, are given in a later* section.)

III. Separate Laboratories and a common Lecture Room.

Where the numbers are large, the same room cannot be utilised both for teaching and practical work, and separate laboratories for physics and chemistry with a common lecture room find favour Such an arrangement is necessary in the case of large schools with a few divisions in each form. (For details of a lecture room see page 7) Owing to limited laboratory accommodation which cannot be increased, pupils are taken in batches for practical work while for theory they go together. More work is thus thrown on the science teacher and special difficulties arise in preparing the school time-table. In cases where pupils take up both physics and chemistry the batches may attend the laboratories alternately for practical work while they take their lectures together in each subject.

As apparatus needed for one subject has to be kept ready on the table while another subject is being taught, a common lecture room often leads to distraction of attention among pupils, even assuming that the table space available is not cut down inconveniently thereby. A common lecture room should be situated between the chemical and physical laboratories as shown in plate 4 A small preparation room next to the lecture room is essential.

IV. Separate lecture rooms and separate class rooms.

By far the best arrangement is to have a separate lecture room and a separate laboratory for each of the subjects physics

ond chemistry. In large schools where there oro several divisions in each form, tho science work would be considerably facilitated by setting apart a laboratory for each form in charge of a single teacher.

4. *Laboratory Accommodation.*

A laboratory may consist of the following rooms :—

(*a*) For physics—(*i*) a lecture room, (*ii*) a practical class room, (*iii*) an apparatus room, and (*iv*) a mechanics room.

(*b*) For chemistry—(*i*) a lecture room, (*ii*) a practical class room, (*iii*) a balance room, (*iv*) a preparation room, (*v*) a store room, and (*vi*) a still room.

Arrangement of rooms in a Laboratory.

All rooms allotted for science work should be contiguous ond not in distant parts of the school. They should preferably be on one floor ond each room should be so placed as to get sunlight reflected into it by means of mirrors when required. A separote block for science is recommended, and if the first floor has also to be utilised for science teaching, the rooms on the first floor may be assigned to chemistry while those on the ground floor may be allotted to physics. A broad staircase is odvisable; a circular one should in no case be permitted. It is undesirable to locate the laboratory on the second or third floor as the carrying of apparatus and materials is rendered difficult and risky thereby In any case, the rooms intended for one subject should all be on one floor; a store room and laboratory on one floor and a lecture room on another floor should be avoided.

The science block should have verandahs all round and should be provided with plenty of inlets for air and light. It should run preferably east to west so that direct sunlight may not get into the rooms, and should have sufficient clear space on the south so as to allow sunlight into the rooms for experiments by reflection from mirrors placed outside.

If the building has to be built north to south there should be deep verandahs on the west to keep off glare and direct sun-

light during working hours. Sufficient space should be allowed for the expansion of laboratory accommodation when needed, and small outhouses should not be built near the main block.

Except in big schools all the rooms specified above need not be provided for separately in every laboratory as some may be combined in a single room. In small schools a table placed in a corner may be used for tools and repair work, and there need be no separate preparation and balance rooms.

The arrangement of rooms in some laboratories is shown in plate 4. Positions of doors only are shown and those of windows are not inserted. Rooms may be arranged in double rows with passages between them or in single rows. In either case, the entrance into each room should be only by one door easily accessible to pupils. Considerable space becomes available if verandahs are protected by iron gratings or wooden palisades and gates are provided for entrance.

The preparation room should adjoin the lecture room and the balance room should be by the side of the practical class room and opening into it. Two lecture rooms should not be adjacent. There should be as far as possible, only one entrance into the laboratory. By this arrangement the entrance to the laboratory is under the eye of the teacher or of an attendant, and the verandah and corridors can be utilised to their full extent.

A dark room is not necessary for elementary work, but one may be provided where space permits for facilitating the work of the teacher in preparing lantern slides of local scenery required for the teaching of elementary science.

Preparation Room.

A separate room for the teacher's preparation is necessary for chemistry work. This room should adjoin the lecture room or laboratory and should be provided with a table 10 feet by 2 feet 8 in. by 2 feet 9 in. along the wall and with shelves and cupboards for storing apparatus. A sink should be fixed at the end of the table and a fume cupboard should be accessible from this room. A glass blowing table 3 feet by 2 feet with a blowpipe and bellows should also be provided. A room 20 feet

by 10 feet will be sufficient for the preparation room of a laboratory of this kind.

A separate preparation room is not necessary for physics teaching, but when the same lecture room is used by more than one teacher and in successive periods, a small room having demonstration apparatus stored in cupboards should be provided adjoining the class room. A room 10 feet by 20 feet will be sufficient for the purpose, and may be also used as the science masters' common and library room.

Store Room.

No separate room is required for storing physical apparatus, but one is necessary for chemical apparatus and chemicals. The size of the room depends on the strength of the school and should in any case be capable of holding at least a year's stock. The room should be provided with suitable racks and glazed almirahs and should be in the custody of a responsible person.

Apparatus and chemicals should be kept separate. The apparatus consists mostly of empty glass vessels, light in weight, and as they occupy much space, deep cupboards (see figure 3) may be provided for storing them. The chemicals on the other hand, stored as they are in considerable quantities and consequently heavy, need strong shelving. A rack (see figure 4) which may contain seven or eight shelves running up to the ceiling of the room may be provided. All dangerous and poisonous chemicals stored in more than small quantities should be kept locked in special almirahs and should be under the direct control of one person. Combustibles like petroleum and alcohol should also be securely stored. A small rack apart from the general rack should be provided for storing acids. The planks and legs of this rack should be soaked in paraffin. The floor space about this rack should be paved with non-corrosive materials and should have arrangements for washing it when needed. A suitable drain and water supply close by are therefore required.

The chemicals to be used after removal from the store and the sub-stock may be placed in the class room or the preparation room.

Balance Room.

A separate balance room adjoining the practical class room is often recommended for chemistry work. The protection of the balances from the noxious acid fumes and vapours of the laboratory is thus secured. A separate balance room is absolutely necessary when regular quantitative and qualitative analysis forms a part of the school course. During the first few years of a laboratory course, however, when the attention of the teacher is often needed while the pupils are at work, the holding of classes in separate rooms for the balance, takes pupils away from his personal supervision. Where handling the balance is itself an art to be acquired under the teacher's personal supervision, a separate room is not desirable The balances should therefore, be kept in the laboratory along with the working benches.

In a chemical laboratory, balances with knife edges and planes made of agate and not of steel are not seriously damaged by the atmosphere, but the general appearance may become unsightly and pupils are not likely to treat them with due care. The balances in such cases may be provided with double covers. Strong acids, especially nitric acid, should not be allowed to be boiled nor sulphuretted hydrogen generated in the same room. Proper precautions taken by the teacher against the production of these acid fumes in the practical work room will mitigate these inconveniences. Portable fume cupboards (see figure 5) similar to balance cases may be placed in the verandahs adjoining the practical class room. Disturbances from wind will be obviated thereby.

5. General Description of Rooms.

The laboratory should be well lighted and ventilated. Plenty of light should come in from the sides and ample provision should be made for sky lights. The rooms should have high walls as lofty roofs give a large volume of air in which fumes and vapours are diffused. There must be openings near the ceiling for the escape of the hot gases generated by the large number of burners used. Direct sunlight should be excluded from the working benches and excessive glare should be avoided.

Length.—Thirty feet to thirty-five feet is the usual length for a room when the breadth is twenty feet to twenty-five feet, and in no case should a pupil be seated farther than 30 feet from the teacher. No massive pillars should be allowed in the middle of the room. Slender pillars may be allowed provided they are fixed in such a manner as not to obstruct the free movement of the pupils.

Breadth.—The usual breadth of a laboratory should be 24 feet to 30 feet. This will allow at least five pupils to sit in each row. Sufficient space for wall cupboards and balance cases will then be available along the sides of the room and a free passage on either side of the working benches will also be possible. When, however, the strength of a science section does not exceed 16, a breadth of 20 feet may be allowed as a special case, while this breadth will be found ordinarily suitable for other classes of larger strength. Hence converting an ordinary room of 20 feet breadth into a laboratory is not recommended except in cases where the strength in the science section is small.

Height.—If the ceiling is flat, the walls should not be less than 14 feet high. If it is sloping and tiled, the walls should be at least 16 feet high in rooms of ordinary dimensions. In some school laboratories very high roofs with balconies running along the walls at a height of 8 to 10 feet are found. These balconies are reached at one end by ladders and are used to accommodate shelves and cupboards for storing apparatus. Such an arrangement is not desirable as the carrying of apparatus up and down the ladders is risky. Sufficient storing space should be provided below the working benches, and in wall cupboards. Separate store rooms adjoining the practical rooms on the same floor are preferable.

Floor Space.—Thirty to thirty-six square feet of floor area per pupil is a suitable allowance for a general laboratory. This space allows for fittings along walls, demonstration table, general sinks for cleaning, balance cases, etc.

Windows.—Windows should be in pairs and opposite to each other, the space between any two consecutive windows or doors and windows in the same wall being not more than

5 feet. Increased wall space for storing apparatus can be secured by the provision of only one *entrance* into the room, all the other openings being windows. Windows should have their sills at a height of 3 feet from the floor, the space below the window sill being formed into a recess to accommodate a shelf or cupboard. (See figure 6.) The total wall space taken up by windows and ventilators should not be less than a fourth of the floor space. The size of a window should be at *least* 4 feet by 5 feet. It should be provided with wooden panelled shutters and glazed shutters the latter to be used during working hours as a protection against strong monsoon winds.

It is an advantage to have blinds for the windows. A black fabric which can be drawn on a rod or wire across the window will serve the purpose Roller spring blinds are not recommended as they are costly and need frequent repairs.

Arrangement of Benches.—The disposition of working benches is a matter of considerable importance The arrangement of benches should be settled before the plan of the room is drawn up, due consideration being given to the maximum number of seats to be provided. The arrangement should be such as to allow easy supervision by the teacher from his seat, to give free space to the pupils to move about when necessary, and to allow the teacher to attend to any pupil without disturbing the others at work Faulty distribution of light and shadow will affect the pupils' eyesight and also render the work of observation with scientific instruments difficult and unreliable. Working benches can be arranged in various ways as shown in plate 5.

In the case of classes exceeding 30 in strength the length of the practical class room will necessarily have to be increased to 40 feet or more. The teacher's table may be fixed in the centre of the room with the working benches placed on either side, the distance between the teacher and the farthest seat not exceeding 30 feet (see figure 7).

Floors.—Floors may be constructed of various materials such as Cuddapah slabs, concrete plastered over with cement, pressed tiles, and square bricks. In selecting a material it

should be borne in mind that cuttings will have to be made in the floor for the various pipes leading to the working benches and lecture tables and for the necessary drains. Concrete flooring owing to unequal settlement, cracks on the surface, becomes cut up unevenly and needs frequent renewal. Cuddapah slabs are cold to the feet and unless smooth and polished are not easily washed and dusted. Asphalt flooring is not recommended as the surface becomes uneven when tables and stools are placed on it. Square bricks with good pointing may be used. They are easily cleaned and are dry and comfortable for bare feet. The level of the floor should be the same throughout the laboratory and the top surface of the sill of door frames should also be in the same level. In no case should the level inside a room be uneven The pipes should run along open drains covered with iron gratings flush with the floor level (for details of drains see page 32).

Walls.—Bricks are to be preferred to stones as it is easier to insert fittings when walls are made of the former Wooden blocks provided at regular intervals while the wall is being built will be found useful when fittings are being put up. The walls should be plastered and have a smooth, glazed and durable surface. White paints may be used to glaze the surface. Strong colours should not be used. Empty wall space can be advantageously relieved by suitable and instructive pictures. Portraits of celebrated scientists and enlarged plans of appliances and apparatus can be exhibted

Inaccessible corners and projections should be avoided. Where openings for ventilators are made at a height, the lower surface of the opening should be sloping and not flat. (See figure 8.)

The wall space between the sill of a window and the floor of the room is usually wasted By having a single layer of bricks for this portion of the wall and fitting up a cupboard or a series of shelves in the recess so obtained, this space can be utilised. (See figure 6).

When ventilators are fitted into the walls, they are often provided with glazed swinging shutters manipulated by double cords hanging down the wall. Such cords are unsightly and cut off much wall space which might otherwise be used for

fitting up apparatus, charts, etc. To overcome these disadvantages, ventilators may be of a fixed pattern. The plan of a double glazed fixed ventilator is shown in figure 8. Such an arrangement ensures free ventilation and light and prevents the ingress and egress of birds, etc. The two glazed shutters are not in one vertical place.

Not infrequently rooms have to be partitioned after construction Brick nogged partitioos are recommended as they occupy little spaco, are light and can be erected on a first floor even when there is no wall on the ground floor corresponding to the partition

6. *Details of Working Benches.*

The tables used by pupils for practical work are usually known as working benches They are either single or double, single being intended to seat pupils on one side only while double benches accommodate two rows. Single benches and their details have been described already (see page 4.)

Double beoches should be three to four feet wide with a length of about 3 ft. 6 in for each pupil. Table tops formed partly of hinged planks supported on hinged brackets are unsteady and give rise to new difficulties in dealing with apparatus. They are therefore not recommended. Benches should be placed sufficiently apart to allow a person to pass freely between two pupils who are working back to back in two adjacent seats or benches. They should be placed across the room or lengthwise between opposite pairs of windows so that the shadows of pupils may not interfere with their work. The table should be so placed as to leave a space of at least 3 feet between it and the wall, and where cupboard and balance shelves are attached to walls the distance should not be less than 4 feet 6 in.

The height [illegible]

so [illegible]

obse [illegible] them without stooping. Such a height is also convenient if a pupil has to sit on a stool to make adjustments on apparatus placed on the table and prepare records. The height of 2 feet 10 inches is suitable to pupils whose average age is 15.

The top of the bench may be made of teak of about 1¼-inch thick. It should be well planed and varnished. Teak resists the action of acids and alkalies very well and withstands heat. The top should have a free edge at least two inches wide all round to enable clamps to be used for fixing apparatus. For this purpose, the rims should not be rounded or bevelled, but should be rectangular.

The drawers provided opposite each seat should be at least six inches deep and should have stops on the sliding frame so that they may not be pushed in farther than the front surface of the legs between which they are placed. They should be made to work smoothly between guides without lateral movement. The height of the frame supporting the drawer should be such as to allow free movement of the knees of the pupils seated on the stools while at work. The height of the stool should be adjusted so as to permit the pupils to sit at the table comfortably.

The cupboards below the drawers should be less deep than the drawers and should leave sufficient knee space for the pupils to use the table top conveniently and avoid unhealthy postures while writing.

There should be at least a space of three inches between the floor and the lower surface of the cupboard so that the floor may be washed when required.

Short working benches, say, four feet long, which would seat only two pupils, are not recommended for elementary laboratories as they are costly and lead to waste of space. Long benches intended to seat more than five pupils on either side ought also to be avoided as the pupils seated at the centre are not easily reached. No bench should be longer than 17 feet or shorter than seven feet

As the bench tops are designed for the convenience of pupils while standing or sitting, the stools should generally be two feet high, but as this height prevents the shorter pupils from having their feet on the floor while seated, the bottom plank of the cupboard may be made to project by about three inches in front to serve as a foot-rest. Such a support allows pupils to stand or sit close up to the bench while at work.

Physical Working Bench.

In plate 6 are set out the details of a bench for eight pupils. Only one drawer is provided for each seat. It is wide enough to hold a drawing board.

A physical bench may have fitted on to it in the middle a horizontal wooden rail 2 inches by 3 inches running the whole length at a height of 3 feet above the bench top. Details are shown in plate 9. The rail will support the gas pipes and may be provided with hooks at suitable distances for suspending spring balances, etc. The rail may also have vertical iron rods fixed on to it along which may run rings and adjustable clamps for supporting flasks, clamping tubes, etc. As it may be difficult for the smaller pupils to reach the hooks if a single rail is placed above the centre of the table, double rails one foot apart may be provided in place of the single rail as shown in the plate.

As the cupboards below may be used for storing physical apparatus, the partitions between opposite seats may be dispensed with. Such an arrangement will also facilitate the storing of apparatus of larger dimensions than can be accommodated in cupboards placed along the walls.

Chemical Working Bench.

Plates 7 and 8 contain the detailed sections and dimensions of a chemical working bench intended to seat eight pupils. A horizontal rail supporting the water and gas pipes without interfering with the table space is laid over the table along its length. The cupboards below the bench have a horizontal shelf plank forming two shelves in each, and this plank is cut off at one corner so as to have the whole height of the cupboards available for holding tall apparatus, *i.e.*, funnel stands, etc. The sinks are common to adjacent pupils and are fixed independently of the drawer and cupboard space so that the joints and drain pipes may be examined periodically and kept in good repair. Small trays with partitions capable of holding half a dozen bottles of wet and dry reagents may be put on the tables when the pupils begin their work and be removed at the end of the lesson to side shelves on the wall or at the end of the

table. These trays will be sufficient for high school work. For work of a more advanced nature involving the use of many reagents, bottle racks capable of holding about two dozen bottles on each side arranged in two or three rows (see plate 9) may be in the middle of the table and may extend to about half the length of each seat. These shelves should not have wooden doors as the teacher from his seat should have a clear view of the pupils (For further details see plate 9). Further sliding doors do not work smoothly after some time and hinged doors often disturb the bottles on the benches or on the top of shelves. Open shelves, however, accumulate dust, etc.

Opposite each seat are two drawers and two cupboards with separate locking arrangements. One set may be assigned to a pupil of one class and the other to one of another class, so that the same table may be used by two classes in different periods.

In plate 9 are given further details of the additional fittings that may be attached to the physical and chemical benches for greater convenience of work. The reagent shelves are of an open type 1 foot 6 inches high, 1 foot 6 inches long and 9 inches broad. Each shelf can hold three rows of reagent bottles on either side and cross reepers are fixed midway to keep the bottles within their half of the shelf space on either side. The edges of the shelf planks are provided with slightly projecting stops in front and the sides of the shelf are planked while the front is left open. The fittings below the bench top are not shown in this plate.

Sinks.

Sinks should be of white glazed porcelain as this material can be thoroughly cleaned. For pupils' benches the most suitable size is 10 in. by 8 in by 6 in (inside measurements) and 20 in. by 10 in. by 6 in. for the lecture table and washing sinks along the wall. The latter should be provided with outlet, and overflow at the sides, and all should be fitted with perforated fireclay stoppers.

A sink common to two adjacent seats is preferable to one common to two opposite seats or four (two being on either side) and the nearer edge of the sink should not be farther than 6 in. from the edge of the table. On the working benches the

water taps should be provided with screw down valves and corrugated nozzles and the special taps on the bigger sinks should have two side taps and the central nozzle should be at a height of 10 in. from the table top. (See figure 2.) The top surface of the sink should be flush with the table surface, and the sinks common to adjacent seats may be provided with wooden covers. The arrangement will add to the table surface available in experiments where the tap is not frequently used. A hole should be drilled through these covers immediately below the nozzle of the water tap so that any water dripping from the top can pass into the sink when the cover is in its place.

Every sink should drain directly into small washing sinks with syphon outlets placed on the floor and near the drain so that any strong acids thrown into the sink by chance might be diluted in the washing sink before running into the drain.

The space below the sink could be provided with a shutter and might be used for retort stands and other tall pieces of apparatus supplied to individual pupils. It could also be used for the 'waste box' into which should be thrown broken pieces of glass, used matches, used up filter papers, etc. Such articles should never be thrown into the sink The box should be left outside the cupboard during working periods and should be replaced in the cupboard after emptying it at the end of a lesson. Tin is the best material for such boxes.

7. Lecture Rooms and Fittings.

The lecture room in a science block is usually planned to accommodate more than the usual number of pupils that can be admitted into a class, for occasions will often arise when more than one general class will have to be brought together for lantern and other lectures on scientific topics There should be independent access to this room so that it may be used even when all the other rooms of the laboratory are locked up.

In plate No. 10 is given the plan of a lecture room with gallery. The room is 24 ft. broad and 36 ft. 6 in. long with seating accommodation for 80 pupils. It could accommodate about 100 pupils on special occasions. Figure 1 in plate 10 is a section of the gallery. The seats in the first seven rows are on masonry platforms and the last three rows are on a

trellis wooden frame, the sides being planked and the inside being fitted with shelves. The space so partitioned can be used for storing purposes, and is accessible through one or two doorways from the verandah behind the lecture room. There is no platform provided for the lecturer. The positions on the wall of the rolled lantern screen (L. S.) and diagram frame (D. F.) are also indicated. In figures Nos. 2 and 3 of the plate a platform for the lecturer and equal stepped galleries for pupils are shown. From the inclined lines drawn in figures 2 and 3 it will be seen that all the pupils cannot have an uninterrupted view of the teacher. This defect is minimised by providing a raised platform for the lecturer. This plan of gallery is often adopted in class rooms for literary subjects.

The windows in the lecture room should be provided with blinds to be drawn up when the lantern is used or be fitted with both wooden and glazed shutters. Ventilators close to the floor level and near the roof should be provided for free ventilation without admitting light.

There should also be a long black board not less than 7 ft. by 4 ft preferably with a sliding mechanism, and also a squared black board. Sufficient wall space should be available behind the teacher for putting up plans and maps. A rolled screen in a suitable case for projecting lantern pictures may be attached to this wall. It can be manipulated with cords.

For carrying diagrams, a light trellis frame 3 feet broad and 10 feet long, may be suspended in mid air by pulleys and ropes from the ceiling, a little behind and over the lecturer's head. It can be lowered or raised and the diagrams may be conveniently removed or put on, for which purpose the articles of the stationery shop known as 'bull-dog' paper clips will be found very useful. Drawing pins destroy the corners of the diagrams ultimately and they are not so good as the clips.

Plans and details for physical and chemical lecture tables suitable for a room 20 ft. broad are given in plates 11 and 12. The length of a lecture table depends on the size of the room. For high school work a table 10 ft. long will generally be sufficient for physics, while for chemistry work a length of 12 to 14 ft. is to be preferred. Three feet is a suitable height. Every lecture table should have gas and water laid on at con-

venient points. Gas taps 2 ft. apart should be fixed at different places on the table. The central bay in each table is provided with a drawer, and the space below, which is left open or fitted up with a narrow cupboard, allows room for the lecturer's knees.

The side of the lecture table towards the class is panelled while the lecturer's side is converted into cupboards, drawers and open shelves to hold the various stands and miscellaneous pieces required in demonstration work. Water is laid on each table, the sinks being lower than the table and supported on brackets attached to its sides. The chemistry lecture table, besides having two sinks and taps at its ends, has extra water taps in the middle for use in connection with condensers, etc. No sinks are provided at these taps.

The table tops are usually made of teak and the free edge of the plank is broad enough for clamps and for carrying gas and water pipes on the lower surface.

It would be convenient in chemical laboratories to have a cupboard or a series of shelves on the back wall for reagents, jars, bottles, etc., which may be readily accessible to the teacher. The fume cupboard should also be in the back wall.

A platform for the teacher is not recommended as freedom of movement is restricted and there is the risk of tripping during demonstration work.

The lecture table may be provided with an optical lantern, a roller screen being put up on the wall opposite. It would be an advantage if the picture could be projected on the wall behind the teacher or on a screen across a corner. Pictures when exhibited in such a position can be seen direct by the whole class, while pictures projected on a side-wall are not properly seen by the pupils seated close to that wall.

Gallery.—Large classes should be provided with galleries which will enable all the pupils to have an uninterrupted view of what is placed on the lecture-table. For this purpose the line of sight from the eye of a pupil to the table should be at least six inches above the eye-level of a pupil in the preceding row of seats. The details of such a gallery are shown in plate 10. The sloping lines drawn-in figure 1 of the plate are drawn from the eye-level of a pupil to that of the lecturer in his seat,

the lines being drawn for different rows. The line of sight drawn for one row has a rise of six inches over that of the preceding row so that a pupil in a row can look over the head of the pupil in the preceding row and thus all pupils in a row can always have an uninterrupted view of the lecturer however closely they may be seated in the preceding row.

There should be three gangways in a gallery—one at each end and one at the centre. The breadth should be at least two feet (2 ft.) and the central gangway should extend upto 4 or 5 steps at least. The central gangway enables the teacher to approach all the seats and is particularly helpful in conducting exercise classes when the note-books of pupils have to be examined while the pupils are seated. Each landing should be at least 2 ft. 9 in. broad and be reached by easy steps. The windows at the sides of the gallery should be raised to the height of the seat opposite to them and the shutters when open should not project into the gangways but should be folded double and placed on the sides of the windows. The shutters opening outwards should have hinges to keep the windows flush with the wall when they are open.

The landings of the gallery when constructed on a trellis frame should be planked in front and on the sides The falling of books, pencils, etc., on the floor and the accumulation of dust and rubbish in inaccessible places will thus be avoided. The space below the upper stages may conveniently be utilised for storing apparatus as shown in plate 10.

The benches should have sloping backs, and the space between the nearer edge of the seat and its desk should be at least five inches so as to allow pupils to move along the bench freely or to stand comfortably.

The backs of the seats should never be flat; they should be sloped to the back of the student and the seat made thoroughly comfortable. (The details of the slope are not shown in the plate). The small additional cost required for this comfort is really an economy on the ground that the brain power of the teacher is the most valuable article employed and a waste of that, attributable to inattentiveness in the audience caused by uncomfortable postures should be avoided at all costs.

The acoustical properties of a lecture-room depend on the nature of the surface of the walls, floors, etc., on the air space behind the teacher and above the seats, and the general direction of the wind. A large amount of empty space above and behind the lecturer should be avoided. If each pupil has an uninterrupted view of the lecture-table and the lecturer, the lecturer's voice will be better heard.

For lantern lectures, one of the seats and its desk in the first row (see the plan in plate 10) may be covered with a temporary platform which will just accommodate the optical lantern. The acetylene generator can be placed below. Pictures can then be projected on the screen behind the lecture-table.

In plate 13 are detailed the dimensions of the parts forming a seat and the desk and landing of a gallery. The front row of desks is shown panelled; the seats are formed of equally spaced reepers, the top surface of which is given a suitable curvature. The back of one row is fixed to the desk and supports the next higher row Each landing is 2 ft. 9 in broad The rises (R.R.R.) of the landings in the back rows are panelled to enclose the store behind the gallery which is accessible by the back doors The planks P_1 and P_2 indicate the shelves in the store. P_2 is shown in elevation being the shelf plank on the sides of the gallery and P_1 is shown in section being the plank in the shelf parallel to and below the seats in the gallery.

8 *Details of Special Fittings*

Workshop:—No laboratory can be considered complete without an equipment for making simple apparatus and executing minor repairs Even in schools having manual training classes, provision for this purpose with special fittings, for metal and wood work, etc., should be made. Such equipment besides enabling the laboratory work to be done without interruption allows many improvements suggested by teachers and pupils during the course of practical work to be carried out at once and tested. Since it is the labour and direction that cost more than the materials employed, it will be economical in the long run to have a workshop attached to the laboratory. There is an additional advantage of affording a preliminary training to such of the pupils as have a taste for mechanical work.

A set of tools required for wood-work and metal work and benches specially made for the purpose are necessary. The elevation and section of a tool chest is given in fig. 10. A plan of a bench for wood-work is shown in plate 14. The bench is 4 ft. by 2 ft. 8 in. high, with three drawers at one end. The top is made of teak of 2 in. to 3 in. thickness supported on legs of 4 in. square section. Adjustable wooden stops with screw adjustment for height are provided at the corners. The table top has at its centre a depression of 1 in. running along its length, its breadth extending to a third of the breadth of the table. This depression is intended for the ordinary tools while they are in use. A carpenter's instantaneous grip vice is fixed at one end of the bench.

A workshop with a small 3½ ft. lathe, one set of tools for metal work and another for wood work, a glass blow-pipe table and a soldering table with accessories will be a very useful adjunct to a laboratory in a hig school. An intelligent carpenter can be easily trained to do all the requisite work.

Such workshops are best located in small outhouses away from the main building but easily accessible from it.

Black board.—Plain blackboards should be provided in the lecture room and in each laboratory. There should be also a spare blackboard with squared white lines on it one inch apart with every fifth line marked red for putting on plans, graphs and diagrams. These boards should be attached to the walls as boards on easels occupy too much space. Portable separate stands for sliding boards are unnecessary. The frames for sliding boards should be fixed to the wall behind the teacher. The boards can be counter-weighted by a cord and weights at each end sliding into a hollow frame with a pulley at the top. Flexible wire ropes are to be preferred to cotton cords for the suspension of the sliding boards. When the board is fixed the bottom edge should be about 3 ft. above the floor. An additional board can be provided in the Chemistry class room by attaching a sliding board as a counter-weight to the sliding doors of the fume cupboard which should be fixed to the wall behind the teacher (see plate 17).

The board should be made of teak planks one inch thick and coated with a black paint which presents a smooth but not

a polished surface. A grooved shelf about 2½ in. wide fixed along the bottom edge of the blackboard is useful for catching the dust and holding the chalk.

The asbestos cement material known as 'Eternit' and by other names makes excellent blackboards; it is light and cheap but since it is brittle it should be used only for blackboards affixed to walls.

Gas Supply.

Gas is more convenient than kerosine stoves or spirit lamps In elementary laboratories provision for gas may be made, but it is not absolutely necessary. In large schools it will be economical to arrange for a gas supply either from a gas main in the neighbourhood or from a special installation. Gas for heating purposes is usually laid on to working benches and lecture tables at suitable points and double taps with nozzles for attaching rubber tubing are provided in the middle of double benches. For blow-pipe work, special tables may be fitted up with special gas taps.

If a special gas installation * is decided upon, a 500 c. ft. gas holder with a cement tank and small producers will be found suitable.

In the absence of a gas supply, a pair of aetna burners may be used with kerosine for high temperatures and strong heating Primus stoves may be used for rapid heating and boiling work. With care the former can be used for glass blowing Kerosine and spirit blow pipes worked by a foot bellows are also available in the market but they are not very satisfactory. For ordinary heating a spirit lamp, though very feeble, will be found sufficient for very elementary work

Water Supply.

A water supply tends to neatness and quickness of work. For chemical work there should be a water tap to each seat, while for physical work water taps may be fixed at convenient

* Messrs Mansfield and Sons of Calcutta supply them. Cheap kerosine may be used for producing the gas.

Messrs. DeLsitte Lighting Co, Bombay, have plants for the production of petroleum gas This plant occupies little space and needs no expert to look after it.

places. Owing to the size of certain apparatus the height of the tap above the sink requires careful adjustment. Taps of special patterns have to be provided for developing tables fitted up within the dark rooms.

Water should always be supplied with some pressure from a reservoir placed at a height, usually on one of the walls of the building. Direct connection of the taps with the town mains is not recommended as the supply in the laboratory cannot be relied upon for uniform pressure and quantity. A cubical iron tank 3 ft. or 4 ft. cubed will be found suitable for the reservoir.

The taps supplied to each bench should have a control stop cock at one end of the bench and there should also be a main cock at the reservoir controlling the whole supply. The tap fitted at each seat should be of a screw plug type so as to regulate the supply of water and prevent leakage. Ordinary turn taps leak when they wear out and the flow cannot be adjusted.

Where both water and gas are supplied, the pipes carrying them should be painted in different colours. The taps also should be different in appearance, *e.g.*, gas taps of lever type and water taps of screw type.

The supply mains should always be of dimensions which will carry a greater quantity than may be ordinarily required.

Sinks.

Sinks of various dimensions are needed in every laboratory. They are made of different materials, the commonest being glazed stoneware*. Such sinks are relatively costly and their joints with waste pipes require frequent attention. Enamelled iron sinks are sometimes used as they are light and less costly, but they do not last long. Sinks made of wood and lined with lead are also used, but they have certain disadvantages, such as an uneven surface, the tendency for water to splash up when used and a dark appearance. They are, however, unavoidable when large sinks of the other varieties are not available and in cases where sinks are required for soldering tables

[illegible] ... into the waste pipe.

Sinks are sometimes placed across a double bench so as to be within the reach of four pupils. They are in such cases 20 inches by 10 inches or 18 inches by 12 inches (internal dimensions) and 6 inches to 8 inches deep. Sinks of smaller dimensions 12 inches by 9 inches (inside) for the use of two adjacent pupils are to be preferred. There should be one or two large sinks in the room where a large number of bottles, flasks, etc., may be cleaned at a time. A vertical board of teak attached to the backwall of the sink and provided with inclined pegs forming a draining board is a desirable adjunct to big sinks. (See figure 2.)

Big sinks intended for washing battery jars, acid bottles, etc., in changes of water should have two outlets, one at the bottom and the other at the side at some height, both leading to the same drain pipe The drain holes at the bottom of the sink are usually provided with perforated stoneware or ebony stoppers which prevent pieces of paper, matches, etc., from getting into the drain pipe. Some are provided with solid plugs which allow the water to accumulate in the sink to the required depth for washing purposes Larger sinks are also provided with hollow cylindrical stoppers with perforations at the top, 3 to 4 inches above the bottom level of the sink. This pattern of stopper or the provision of an outlet at the sides near the edge, serves the same purpose, namely, the accumulation of water up to a required depth, the excess water being drained away. In these two cases, it is assumed that the tap above is left open.

Bottle Shelves—All the solid and liquid reagents to be supplied to pupils, and salts required for practical work should be kept within easy reach. As some of these articles will be consumed in large quantities while others will be used only occasionally, bottles of different sizes are required. Suitable shelves for the bottles should be fitted up. A plan, section, and elevation of a shelf are given in plate 15. Separate shelves for liquid reagents and for solids are recommended.

When the classes are large, more than one shelf for each variety of reagents will have to be provided in different parts of the room.

The lower part of reagent shelves are generally used for the common apparatus issued occasionally to pupils such as burettes, pipettes, and crucibles and gas jars specially used in some experiments. The shelves need not be more than 8 inches deep at the top and 12 inches at the bottom, and should be screwed on to plugs fixed in the adjacent walls.

Balance-Cases and Shelves.—Balances used in very elementary work, such as is usually done in Forms III and IV need not be provided with cases nor need they be of delicate workmanship. They may have steel hooks and suspenders. They need not have knife edges. Weights smaller than 0·1 gramme are not required.

The physical balances intended for the higher forms should be able to carry 250 grammes in each pan and be sensitive to 2 or 3 milligrammes. Balances with agate knife edges and planes are preferable to those with steel knife edges. The former, however, need careful handling and should be provided with cases glazed all round and with sliding fronts.

Balances for chemical work should be sensitive to 0·002 grammes and, as they are distorted by the slightest current of air, should be provided with cases, the door of which can be smoothly and easily moved. Balances with agate knife edges used for chemical work should have a carrying capacity of 120 grammes in each pan and be provided with a box of weights, the smallest being 0·005 grammes. More delicate balances are not needed in a high school. Economy of time and apparatus being important factors in practical work, only small quantities of substances will have to be dealt with and rougher balances will not be useful.

Cases for balances should be made of teak with glazed sides, and should fit the base board of the balance and sit on it leaving the handle for arrestment outside the case. Sometimes larger cases than are necessary are made and the balances are left inside, the base board of the balance being independent of the case. With such cases the balance is apt to be shifted when handled and the zero point is disturbed. They are not popular with pupils.

A common variety of sliding sashes in balance cases is provided with metal stops. These sashes can be pushed up

with one hand, but both hands have to be used in letting them down. Another variety has balancing weights for the sashes and can be moved with one hand. A third variety contains one or two recesses in the frame for the sash to enable it to be lifted up and held in position (figure 10). The last mentioned variety can be easily made and handled. One step in the middle of the frame will suffice for all practical purposes in high schools.

Balances should be placed on shelves fixed to brackets in the walls and should be independent of the tables placed below them. Sometimes they are placed on tables, but this is not desirable. When balance cases are arranged in a row, they should be at a sufficient height to enable pupils to stand and use them. The scale in the balance over which the pointer moves should be a little below the level of the eye. There should be plenty of light in the room and as far as possible no shadows should fall on the balances. Cases should be so arranged as to allow at least 2½ feet of space for each pupil. Where brackets are fitted, tables with cupboards may be placed below them (figure 1). The table top may be used for notebooks and boxes of weights when the balances are being used. It is advisable to fix a rounded fillet along the back of the shelf and the back of the table to prevent the small weights from slipping down between the shelf and the wall or the table and the wall. Drains near by should be covered with planks.

The number of balances supplied for the use of a class should be at the rate of one for every three pupils.

Demonstration Table and Accessories.

Each practical class should have a high table for the teacher to perform experiments on. It should be at least 2 feet broad and 6 feet long, with a water tap and sink at one end, and should be provided with drawers for the teacher's books, class notebooks, etc. It should stand on a low platform 1 foot high. A recess running along the whole length below the table top will be useful for storing long tubes, charts, maps, etc., which cannot be usually accommodated in ordinary cupboards and drawers. (See plate 2.) The demonstration table should be placed as to command a view of all the pupils in the class. The

space between the table and the wall should be at least 4 feet. A shelf for glass tubes, flasks, etc., required for demonstration and for reagents should be close at hand, also another sink for washing the various kinds of apparatus. Near by or attached to the table, there should be a shelf where pupils may keep their laboratory records. There should be a blackboard at least 4 ft. by 6 ft. just behind the teacher.

Laboratory Seats.

High stools are usually provided for the pupils at their working benches. Their height is adjusted to that of the bench. The seats are not provided with backs or side rests as such additions interfere with the free movement of the pupil at the table. They are made with a broad base and a narrow top to ensure steadiness, and for ease in handling a curved hole is made in the top. The stools when not in use should be placed in the recess in front of the cupboard. They may be carried by the pupils to the single work benches round the demonstration table during teaching lessons and brought back at the end of the lesson. (The plan of a stool is given in Plate 8.)

Stools whose heights can be adjusted by screws (fig. 12) are sometimes provided to meet the requirements of different pupils, but, as the screws begin to rock in their nuts and the seat becomes unsteady they are not recommended. In providing laboratory seats and benches a judicious compromise has to be made between the needs for (1) free movement, and (2) comfortable posture in sitting, and in standing while performing experiments.

Wall Cupboards for Apparatus.

The physical apparatus should be arranged according to some system of classification in cupboards placed along the wall. The dimensions and plans of such cupboards are given in plate No. 16. The usual height of these cupboards is the same as that of the working benches. Tall almirahs along the walls are not recommended as they interfere with the wall space so much needed for various purposes, and extra table space which is often required by the pupils is curtailed. The cupboards

should have teak and not glazed shutters. It may be noted here that glazed shutters should not as a rule be used at less than 3 ft. from the floor. Some of the cupboards may have open shelves with table tops in which the most frequently needed apparatus in the laboratory, *e.g.*, tripods, blocks of wood for adjusting levels, aetna burners, etc., and general stands may be placed. All cupboards with shutters should be provided with locks which can be opened with a common key. The cupboards should fit into the space between the windows and doors. One or two almirahs with glazed shutters for the upper and wooden for the lower half may be put on either side of the demonstration table to hold special apparatus required for demonstration work. They may be 2 ft. deep at the bottom, 1½ ft. at the top, and 7 ft high The tops should be flat.

Drains.

The drains should, as far as possible, be of an open type with iron gratings to cover them They should have smooth sides and surfaces and should have a slope of about 1 inch in five feet. When drains are cut in an upper floor the slope will have to be much less, or special drain pipes will have to be fitted to working benches above the floor level. The section of the drains cut in the floor should be semi-circular with grooves at the top (fig. 13) to carry the gas and water pipes of the laboratory, or cross planks may be provided as bridges at intervals (fig. 14) along the drain with depressions in them to carry the pipes. In figure 13, is shown in section a terrace in which a drain is cut. When a laboratory is located in an upper floor, the depth available for the drain is necessarily limited; the lead for the drains should therefore be as short as possible. The position of the main drain leading from one floor to another will have to be centrally located so that each tributary drain on the same floor is limited in length. The surface of the drains should be water-tight and for this purpose it may be cemented. In the chemical laboratory it may be asphalted and tarred periodically, or may be lined with tarred cement about 1 in. thick. Such drains have been found to be serviceable for many years. The gratings should be made of cast iron pieces of not more than 2 ft. in length, and ¾ in. in thickness, so that

they may be easily removed and the drains washed and the gas and water pipes painted. Wooden covers for the drains are not recommended as they warp.

Fume Cupboards.

Fume cupboards are enclosures within which operations involving the production of fumes and gases can be conducted without harming the operator or vitiating the atmosphere of the laboratory. They should be used in all chemical operations which involve inconvenience to the pupils at work in the laboratory. One or two fume cupboards at convenient points will be ample for elementary laboratories.

When the number of cupboards is limited, one opening into the lecture room and into the practical class so that it may be accessible from both sides is recommended. Plans of two types of cupboards are given in plates 17 and 18. There should be water and gas available at different points in the cupboard, the surface of the table should be leadlined and the sides of the cupboard should be thickly painted with non-corrosive paints. The chimney must be carried up to the top of the building, and it should be wide enough to have a good draught. There should be a gas jet fixed at the top of the ventilating shaft as near the exit as possible for starting the current.

It should be borne in mind that in designing for fume cupboards in the tropics, the outside air is warmer during the working hours than the inside air. Consequently it is more difficult to make an upward current in a vertical shaft by heating the air from below with a small flame. The best result will be obtained when the flame intended to start the ventilation is as near the exit, at the top, as practicable. A very good arrangement is found in having a length of the iron flow pipe painted black protruding free into the air for 4 to 5 ft. This length gets very hot indeed in the sun and the upward draught produced in consequence is found to be considerable.

Fume cupboards are generally placed on the face of the wall or in recesses especially provided for them. Occasionally they are constructed in front of the windows but this arrangement

has the disadvantage of interfering with the free ventilation of the room when the cupboards have to be used frequently. In High Schools portable cases for fume cupboards will tend to reduce the cost of the fittings and will facilitate laboratory work. In elementary chemical laboratories, every batch of three pupils should be provided with such a case. Fig. 5 gives the plan of a fume cupboard case. It will be observed that the dimensions of the case (1 ft. × 2 ft. × 1½ ft.) are such as to permit of its being easily removed to verandahs when it has to be used and stored on wall shelves at other times.

The size of wall fume cupboards should be decided upon with reference to the space required for manipulating the apparatus that may be placed in them. Those used for advanced work and by teachers should not be less than 2 ft. broad and 4 ft. long. The front of the fume closet should be capable of being easily raised or lowered with one hand as the other hand will often be engaged in carrying apparatus to be placed within Glazed doors hinged at the sides so as to project outwards when open are very inconvenient. They also interfere with the regularity of the draught.

The top and sides of the cupboards should be glazed so as to admit plenty of light into the closet. Glazed bricks or tiles are sometimes used to line the wall at the back of the cupboard.

Various materials are used for the bottom of the closet such as slate, stone, lead and glass. It should be borne in mind that it has to resist the action of various chemicals and fumes and to withstand considerable heat from gas burners, etc. A lead surface becomes uneven after use for some time and presents a dirty appearance. When there is continued intense heating, a stone or Cuddapah slab cracks.

9. *Care of the laboratory furniture and fittings.*

Attention to the following points may be found useful:

1. *Varnishing.*—White patches are formed on table tops by the dropping of hot water and solutions of various chemicals during practical work. The surface may be restored to its original gloss and uniform colour by sandpapering the discoloured patch

and a little space all round it and painting on a little shellac varnish. The varnish is prepared by putting the following mixture* in 2 lbs. of alcohol and shaking it frequently for the first two or three days till all the resin dissolves. The preparation is hastened by exposure to sunlight. The mixture should be shaken every time before use.

2. *Use of Asbestos Boards.*—By the intense heat radiated from Bunsen burners and stoves, varnished table tops become rough in appearance and the surface varnish turns black. If not carefully attended to, the teak surface becomes charred in course of time. In cases when heating for any length of time is necessary, the burners and boilers may be placed on small asbestos-lined tin plates. These may be used also for placing hot vessels on. The special tables used for blowpipe work should have asbestos boards fixed on their tops.

3. *Washing.*—It often happens in chemical work that strong acids when being boiled splash on the table and char the surface. Pupils should be instructed to wash the acid at once into the sink. When large quantities happen to fall on the table, laboratory attenders should be called upon to do the washing. When bottles containing strong acids have to be brought to the tables, they should invariably be placed on glazed porcelain acid trays and not directly on the tables. In chemical laboratories drain pipes from sinks should lead into sinks with syphon outlets and not directly into drains. This will ensure the dilution of any strong acid before it reaches the drain.

4. *Polishing metal taps.*—Taps made of bright metal should be cleaned with metal polish every week or painted with white metal paint periodically.

5. *Painting Reservoirs.*—Water tanks should be painted both inside and outside, and if situated near trees should be provided with covers to prevent leaves and twigs from falling into them. After long vacations, during which water is not used in the laboratory, it is often found that the taps are clogged owing to incrustation of chalk. To prevent this, the tank should be kept full and water should be drawn through the taps occasionally.

6. *Drains.*—These need constant attention. The gratings covering them should occasionally be removed and the surface

* Shellac in flakes, 2½ palams; Gum Sandrac ½ palam.

of the drain cleaned. Any pitting of the surface which may occur in a chemical laboratory should receive early attention and be repaired as soon as possible. The accumulation of dirt round pipes laid at the sides of the drain should be prevented and the wooden cross reepers, if used to support the pipes, should be periodically painted to prevent rotting.

7. *Wash for the blackboard.*—Stir spirit varnish with a little lampblack and flour of emery. No more lampblack and emery should be used than are sufficient to give the black abrading surface. The thinner the mixture the better. Lampblack should first be ground with a small quantity of spirit varnish or alcohol to free it from lumps The composition should be applied with a common paint brush to the smoothly planed surface of the board. The surface of the board should be thoroughly dry and hard before it is used. It may be rubbed down with pumice stone if too rough.

8. *Laboratory discipline*—A set of rules of laboratory discipline some of which are given below would increase the average life of the equipment and also the necessary habits are more easily and more cheaply learned at the earliest possible stage

1. Every student should have a seat assigned to him in the laboratory where he will usually perform his experiments. (The seats should be consecutively numbered and the numbers should be prominent).

2. A student should not usually enter the laboratory room in the absence of his teacher or the attendant in charge of the room (The shelf intended for placing record books of pupils should be close to the entrance into the laboratory so that the books may be put in or taken out without any kind of disturbance.)

3. A student should never leave his seat to roam about after his teacher for information, apparatus, chemicals, etc. (The teacher should stop this tendency at the outset; he must make the student put up his hand or otherwise attract the attention of the teacher and then await his turn.)

4. A student should not start weighing until he has ascertained that everything is in order, all the weights, forceps, etc., are in their right positions in the box and the balance pans

clean. (If he starts anything he should be held responsible for all deficits and deficiencies. This should be an inflexible rule rigidly enforced.)

5. No bottle (or stopper) is ever to be placed on a table or bench or anywhere except in its proper place on its shelf and these should be in their places immediately after use. (Otherwise the stoppers get mixed up and the place looks very untidy. *Bottles* and their stoppers should be *numbered with corrosive* ink specially prepared for glass, containing a preparation of hydrofluoric acid and then the right stopper of each bottle can always be found).

6. Waste filter papers and *burnt matches should never be* thrown into sinks. Matches should be blown out cool before being thrown into waste boxes

7. A piece of asbestos millboard, say 8 in. by 8 in., should always be in use on each bench and nothing hot should be ever put anywhere except on the asbestos.

8. Scribbling figures on tables, drawing boards, on walls and loose sheets of paper should never be permitted. (All calculations should be done in the laboratory note book.)

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Note :—Numbers refer to pages—

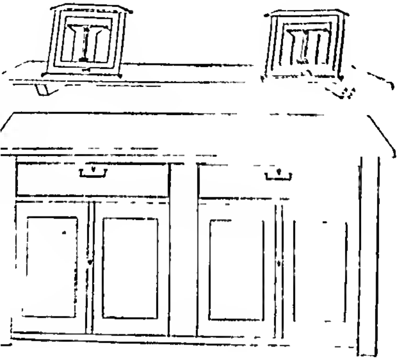


Figure 1.

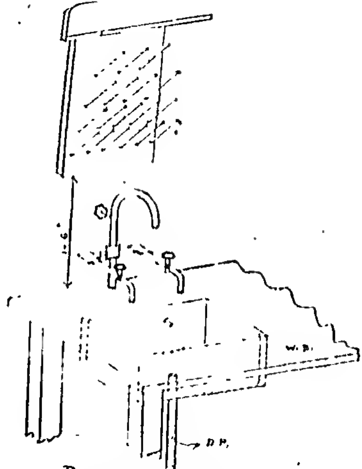


Figure 2.

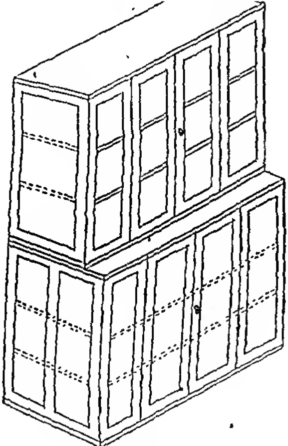
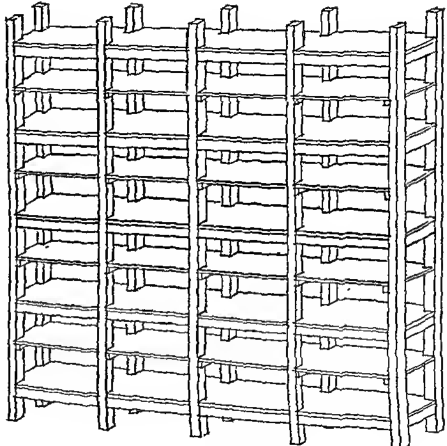


FIGURE 3.



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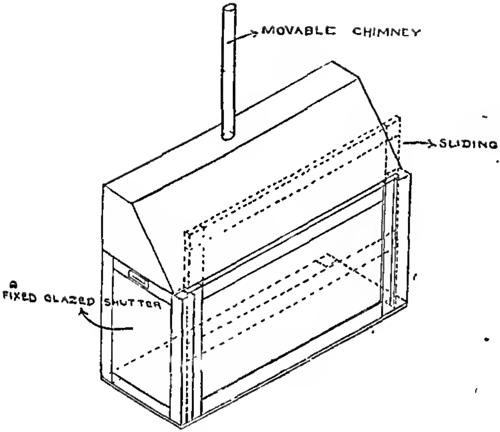


PORTABLE FUME CUPBOARD

TO BE USED IN VERANDAH

FIGURE 5.

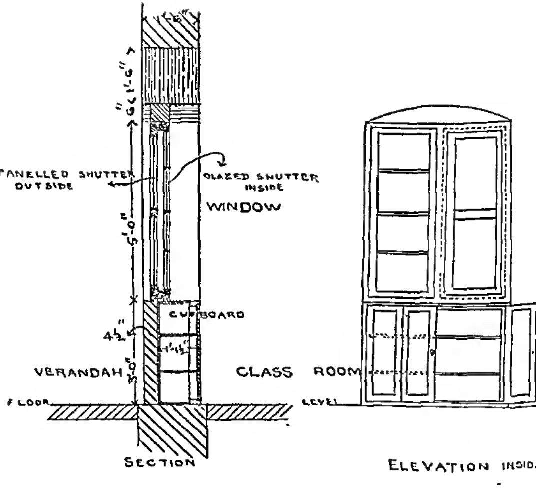

6"
1'-6"
PANELLED SHUTTER
OUTSIDE
GLAZED SHUTTER
INSIDE
WINDOW
5'-0"
CUPBOARD
4½"
1'-1½"
VERANDAH
3'-0"
CLASS ROOM
FLOOR
LEVEL
SECTION
ELEVATION INSID

FIGURE 6.

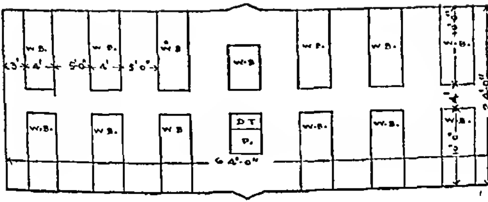


FIGURE 7.

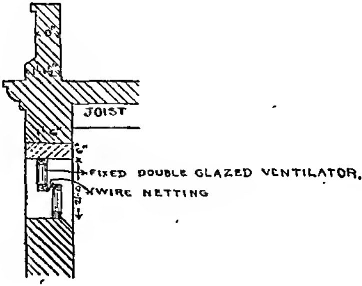


FIGURE 8

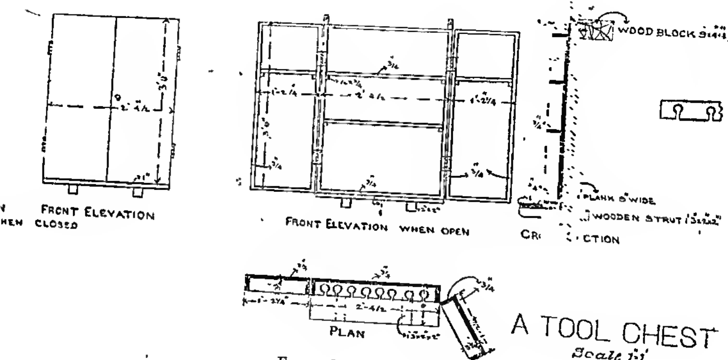
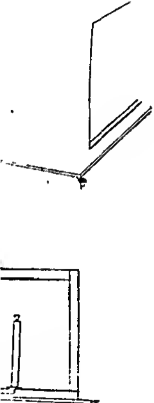

FRONT ELEVATION
WHEN CLOSED
FRONT ELEVATION WHEN OPEN
WOOD BLOCK
PLANK WIDE
WOODEN STRUT
CTION
PLAN
A TOOL CHEST
Scale

FIGURE 9.



[Fig]ure 10.

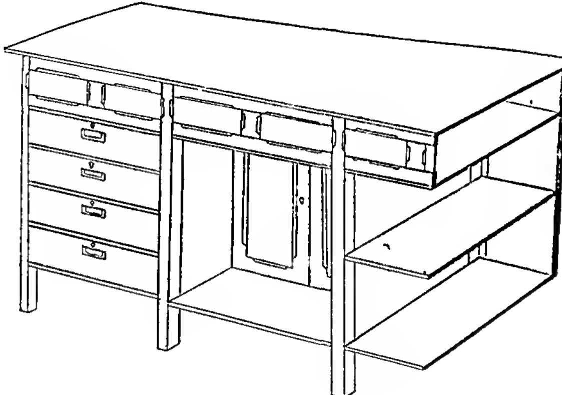


Figure 11.

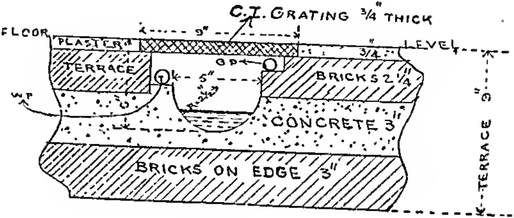


FIGURE 13.

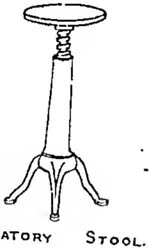


FIGURE 12.

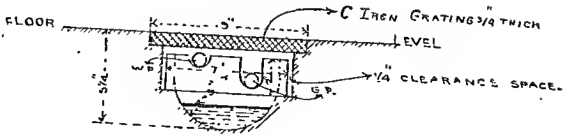


FIGURE 11.

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Report on the enquiry to bring Technical Institutions into closer touch and more practical relations with the employers of Labour in India By Lieutenant-Colonel E. H. deV. Atkinson, R.E., and T. S. Dawson. As. 10.

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No. 1. Rural Schools in the Central Provinces. By H Sharp. Re. 1

No. 2. Vernacular Reading Books in the Bombay Presidency. By J. G. Covernton (*Out of print*)

No. 3. The Educational System of Japan. By W. H. Sharp. (*Out of print*)

No 4. Furlough Studies. By J. Nelson Fraser, H. Sharp and G. W. Küchler. Rs. 2.

No. 5. Training of Secondary Teachers. By H. R James, H Sharp and J. Nelson Fraser. As. 8.

No. 6. Educational Buildings in India. Rs. 5

No. 7. Methods of School Inspection in England. By H O Wyatt. As. 8.

No. 8 The Training of Teachers By H S. Duncan and A. H. Mackenzie. As. 8.

Bureau of Education Pamphlets.

No. 1. Drawing and Manual Training in Punjab Schools. By J. Y. Buchanan. As. 8.